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Abstract

A case study will be presented of a two phase process of development of the hydraulic design of a flood control project incorporating a creek nestled within an urban greenbelt. The green belt reach consists of the existing, 5 to 15 foot wide tree-lined, low flow channel set within an approximate 100 to 150 foot wide floodway to be created by low berms. Any project features proposed for this reach would need to be environmentally and aesthetically acceptable. The design approach taken in developing the flood control and channel stabilization plan for the greenbelt reach will be presented. This approach includes qualitative and quantitative analyses in designing the minimum acceptable measures needed to ensure flow conveyance capability, minimize maintenance and provide for an environmentally and aesthetically pleasing design (USACE,1989a).

Introduction

On several recently conducted studies of local flood control channel projects, the authors have sucessfully applied a two phase process in development of the hydraulic design of major project features. The first phase typically focuses on identifying the basic features required to meet the project flood control purpose and on qualitatively assessing potential project impacts on the stream system's hydraulic, hydrologic, geomorphic and sediment transport characteristics. The end product of the first phase is called the Preliminary Hydraulic Design or "PHD". The second phase focuses on refinement of the PHD to address any questions and/or concerns raised by the PHD. The end product of this second phase is called the "refined" or Final Hydraulic Design. The advantage of using this two phase process is that it gives a distinct checkpoint in the design of project features at which the design can be reviewed, for example by the Local Sponsor and by the Corps' internal technical, environmental and project management elements, to ensure that it meets the project objectives in a safe, efficient, reliable and environmentally sensitive manner. Following is a case study of a flood control project on which this two phase hydraulic design process was applied.

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The Coyote and Berryessa Creeks (Santa Clara County), California Project is presently in the Preconstruction, Engineering and Design (PED) Phase. One element of the overall project is a proposed plan for flood control features on Berryessa Creek which would provide 100 year (design event) flood protection. This creek is located in the south San Francisco Bay area of Northern California, and flows through the rapidly urbanizing area of the city of Milpitas. The project reach extends approximately four miles from its upstream limit near Old Piedmont Road downstream to Calaveras Blvd. where it joins a flood control channel previously constructed by the project's local sponsor, the Santa Clara Valley Water District (SCVWD). Berryessa Creek has existing, undersized flood control features constructed by various entities. Design constraints in the greenbelt reach include minimal right of way, containment of floodflows by leveeing, only (i.e. no excavation) and minimal disturbance to the existing low flow channel and vegetation.

Watershed and Channel Description

Berryessa Creek has a drainage area of approximately 4.3 square miles at the foothill line. The upland (foothills) portion of the watershed is fairly steep and is predominately rangeland with some sporadic residential development. Soil types in the uplands include clay loams on the gentle slopes and coarse gravelly soils on steeper slopes (NHC, 1990). Much of the coarse bed material load, up to small boulder in size, originate from a short, steep-walled canyon-like reach at the foothill line.

At the foothill line, high flows presently spill out of bank due to an undersized culvert. A 1000 foot, unlined "connector" channel spans the gap between the foothill line and the downstream greenbelt reach. Under project conditions, the connector channel will be modified into a rectangular concrete-lined channel and the undersized culvert near the foothill line replaced. This will result in roughly doubling of the flow delivery capability from the foothills to the greenbelt reach. In addition, a sediment basin will be constructed at the foothill line to prevent coarse grain sediments from entering the downstream flood control channel.

The greenbelt reach is approximately 4500 feet in length, having a low flow channel ranging in width from 5 to 15 feet and in depth from 2 to 6 feet on a relatively steep slope of 2 percent. In several reaches, the banks have near vertical sideslopes. The floodway width (created by manmade low berms) is approximately 100 to 150 feet. Evidence of present instability problems include direct abutment of the low flow channel against manmade berms, remnants of previous local bank protection measures, some reaches of steep channel walls and undercutting of mature trees lining the low flow channel banks.

The low flow channel is moderately sinuous, often directly abuting the existing manmade berms and having an average wavelength of 600 feet. It is also lined for most of its length with mature trees with an understory of often dense brush. The bank and bed materials of the low flow channel vary, but are generally composed of silts, sands and gravels.

Overbank widths in the greenbelt range from none where the low flow channel directly abuts the manmade berms to 75 feet. Vegetation within the overbanks ranges from none to mowed grasses where the channel is adjacent to a schoolyard to low brush, weeds and trees. The existing channel and overbank maintenance regimen is unknown. However, the authors have observed the reach in both a heavily vegetated as well as cleared condition.

Two creeks, Sweigert and Crosley, having a combined drainage area of 1.6 miles, enter the greenbelt reach via a storm drain system. Although these tributaries originate out of the same foothills as Berryessa Creek, the majority of their drainage area is urbanized. Thus, it is believed that these tributaries convey a substantially smaller sediment inflow than does the mainstem.

Phase I - Qualitative Assessment of Potential Impacts of Project Features

A review of proposed project features both within and outside of the greenbelt reach resulting from the Preliminary Hydraulic Design process and a qualitative assessment of their potential impact on the hydraulic design and stability of the reach follows:

(1) **Channel and culvert modification upstream of greenbelt.** These features will result in delivery of higher floodflows to the reach, requiring raising of existing levees and inclusion of channel stabilization measures to ameliorate increased potential for channel bed and/or bank erosion due to exposure to these higher floodflows.

(2) **Sediment basin upstream of greenbelt.** This feature will result in a reduction of coarse sediments delivered to the greenbelt area, and hence, require stabilization measures to ameliorate the potential for increased channel bed and/or bank erosion caused by the stream attempting to adjust to the decreased sediment inflow.

(3) **Levee raising through greenbelt.** Similar to (1), above.

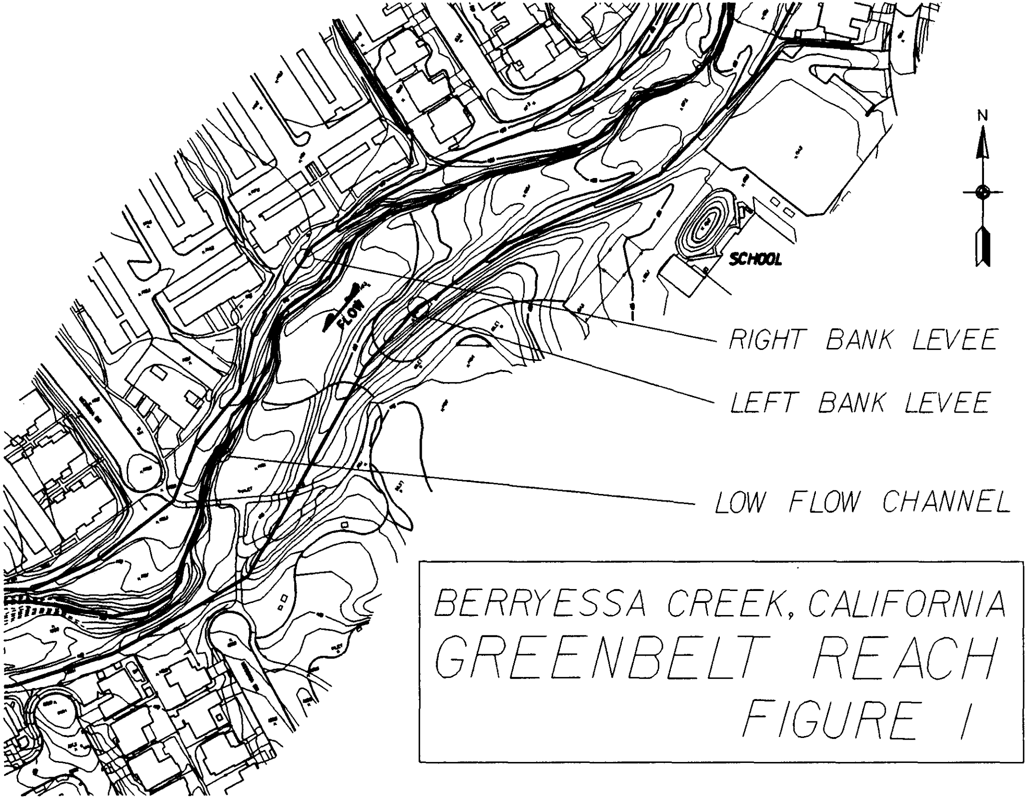
(4) **Slope Protection Measures.** Construction of slope protection for the levees where the low flow channel directly abuts them will result in the destruction of mature trees lining the channel banks and disruption of the low flow channel.

(5) **Retainment of Existing Vegetation Scheme.** This maintenance practice will result in subareas of the channel cross section of relatively dense vegetation where low velocities may induce sediment deposition and in subareas of relatively sparse vegetation where high velocities could result in substantial scour zones.

(6) **Retainment of Existing Low Flow Channel.** This may perpetuate the existing erosion problem at locations where the low flow channel directly abuts the levee berm system, thus endangering the reliability of the project's flood control function.

(7) **Combined Effects of Vegetation and Meandering Low Flow Channel.** The existing low flow channel meanders completely across the existing floodway (see Figure 1), essentially creating a partial "screen" of vegetation across the overbanks of the floodway. The effect of this "screen" will tend to increase hydraulic losses and increase the potential for sedimentation in the overbanks.

For more frequent flow events, the project is not expected to substantially affect stability of the floodway because the project will have little or no affect on the delivery of the lower flows to the reach. The existing low flow channel capacity is estimated to be 250 to 500 cfs. These flows have an approximate return interval of 2 to 5 years, which is the approximate range of return interval that has often been reported as that of the "dominant" or channel forming discharge of a stream (Sing,1988, USACE,1989b and USACE,1990) in the San Francisco Bay area. The existing culvert near the foothill line which limits the amount of the higher floodflows which can get into the existing channel has a capacity of about 750 cfs which has a return interval greater than 10 years. Thus, even though this undersized



BERRYESSA CREEK, CALIFORNIA
GREENBELT REACH
FIGURE 1

culvert will be replaced, the discharges that most influence the behaviour of the meandering low flow channel will not be affected.

For less frequent flow events, the project is expected to have some impacts on the stability of the bed and banks of the greenbelt reach. The project design inflow into the greenbelt reach is 1570 cfs. However, the existing, upstream culvert limits the preproject delivery of flows to the reach to only 750 cfs. Intuitively, such a large differential in existing and future flow delivery rates spells the need for channel stabilization works due to the expected increase in stream power and hence erosion capability with the increase in flows. In addition, the materials eroded from the bed and banks of this reach would need to be captured at the downstream end of the reach before they could enter the concrete-lined flood control channels downstream of this reach. The Preliminary Hydraulic Design (NHC,1990) called for 5 - 10 foot wide rock riprap channel stabilizers spaced at approximate 700 foot intervals to arrest any headcuts which may be induced. Maximum computed degradation depth without the stabilizers was eight feet. The PHD also included a secondary sediment basin to capture eroded sediments at the downstream end of the greenbelt.

Phase II - Design Refinements and Associated Quantitative Analyses

The Preliminary Hydraulic Design identified the basic project features required to accomplish the basic project purpose of flood control. It also clearly identified concerns regarding the project-condition flow conveyance capability and vertical and lateral stability of the greenbelt channel. Final refinement of the preliminary hydraulic design is being conducted to "fine-tune" the preliminary design of the greenbelt features to address these concerns. This process will be oriented towards additional quantitative assessment of potential project impacts and the effectiveness of proposed project features to ameliorate these impacts. Analyses will include more detailed fixed bed hydraulic computations to determine a design water surface and freeboard design flood for setting of the top of levees through the reach, and combined channel stability analyses and movable bed computations to determine the optimum number and spacing of the channel stabilizers as well as the volume of material that may be eroded from the reach under average annual and design event conditions. Other design modifications from the PHD that are presently being considered include use of alternative forms (other than full rock revetment) of bank protection to minimize impacts to the low flow channel banks and to the existing vegetation and possibly moving of the low flow channel in reaches where it directly impinges on the levee berm.

One of the particular challenges in this design stage, and which will prove to be the key to a stable and environmentally acceptable channel design has been the question of selection of appropriate Manning's "n" values. These must simulate the hydraulic roughness "seen" by low, moderate and high flows due to the various types and density of vegetation in the floodway, irregularities in shape of the floodway and low flow channel as well as due to the meandering of the low flow channel and associated vegetation across the floodway. These assumptions ultimately impact design costs as higher water surface elevations forces high levees while lower water surfaces might mean higher velocities and the need for more channel stabilization measures. Either under- or over-estimation of these roughness values, in such a steep, high velocity stream can compromise the reliability of the project as well as create an aesthetically unacceptable project caused by overly high levees or excessive channel stabilization works.

Conclusions

A two phase process for hydraulic design of features for incorporation of an urban greenbelt into a flood control project has been described. Phase I of the process allows for identification of major features to meet the project objectives; then, Phase II focuses on refinement of the design of these features to address both technical and environmental concerns. The technical challenges in incorporation of the project with minimal impact to the environmental and aesthetic qualities of the greenbelt are much greater than the more traditional "channelization" project due to the unique features of the greenbelt that have hydraulic impacts which are not readily quantifiable.

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References

Northwest Hydraulic Consultants, Inc. (NHC), October 1990, report entitled *"Sediment Engineering Investigation and Preliminary Hydraulic Design of the Berryessa Creek Flood Control Project"* prepared for the U.S. Army Corps of Engineers, Sacramento District under Contract Number DACW05-90-D-0012, Delivery Order Number 1.

Sing, E.F., 1988, paper entitled *"Stable and Environmental Channel Design"* in Proceedings of the 1988 National Conference on Hydraulic Engineering, Colorado Springs, Colorado.

U.S. Army Corps of Engineers (USACE), November 1989a, Engineering Manual Number 1110-2-1205 entitled *"Environmental Engineering for Local Flood Control Channels"*.

..... USACE, December 1989b, Engineering Manual Number 1110-2-4000 entitled *"Sedimentation Investigations of Rivers and Reservoirs"*.

..... USACE, September 1990, Engineering Circular Number 1110-8-1 entitled *"Stability of Flood Control Channels"*.

Appendix - Conversion Factors

Multiply English Unit	By	To Obtain SI Unit
cfs (cubic feet per second)	0.2832	cms (cubic meters per second)
ft (feet)	0.3048	m (meters)
mi (mile)	1.609	km (kilometer)
mi2 (square miles)	2.59	km2 (square kilometers)
ton (short)	0.9072	Mg (megagram)